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A novel UWB slot antenna with reconfigurable rejection bands

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Abstract: A coplanar waveguide (CPW) fed Ultra Wideband (UWB) slot antenna with reconfigurable rejection bands is presented. Specific band of the rejection is achieved by placing switching diodes over the rectangular slot in the ground plane at a position of effective length of $\lambda/2$ for the center frequency of the rejection band. The rejection of WiMax, IEEE 802.11a and HYPERLAN/2 bands can be achieved by switching the diodes. The simple configuration and low profile of the proposed antenna leads to easy fabrication that may be used in any wireless UWB device applications where reconfigurable rejection bands are required.

Keywords: coplanar waveguide, reconfiguration, slot antenna, UWB

Classification: Microwave and millimeter wave devices, circuits, and systems

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1 Introduction

Ultra wideband communication systems gains much attention by the researchers due to its inherent properties of low power consumption, high data rate and simple configuration. Designing an antenna to operate in the UWB band is quiet challenging one because it has to satisfy the requirements such as ultra wide impedance bandwidth, omni directional radiation pattern, constant gain, high radiation efficiency, constant group delay, low profile easy manufacturing etc [1]. Interestingly the planar slot antennas with CPW fed posses the above said features with simple structure, less radiation loss, less dispersion and easy integration of monolithic microwave integrated circuits (MMIC) [2]. One of the major problems associated with UWB system is the interference from the other communication systems such as WiMax (3.3 GHz–3.7 GHz), IEEE 802.11a (5.15 GHz–5.35 GHz and 5.725 GHz–5.825 GHz) and HYPERLAN/2 (5.15 GHz–5.35 GHz and 5.47 GHz–5.825 GHz) which are also operated in the portion of UWB band. Many techniques also used to introduce notch band for rejecting the interference in the UWB slot antennas. It is done either by inserting half wavelength slits, stripes in the tuning stub [3], or inserting square ring resonator in the tuning stub [4], or with complementary split ring resonator [5], or inserting strip in the slot [6]. All the above methods are used for rejecting a fixed band of frequencies. But to effectively utilize the UWB spectrum and to improve the performance of the UWB system, it is desirable to design the UWB antenna with reconfigurable notch band. It will help to minimize the interference between the systems and to improve the performance of the UWB systems. In [7] RF MEMS switches are used for the reconfigurabilty of rejection band between the frequencies 5 GHz to 6 GHz.

In this paper a new method is proposed to obtain the reconfiguration in the frequency notch bands for WiMax, WLAN 802.11a and HYPERLAN/2 systems by making 'on' and 'off' the diodes placed over the slot that is introduced on the ground plane. This intern changes the tuning length of the slot, which is responsible for the desired frequency notch band. Through our simulation it is also found that the desired frequency notch band can be obtained by inserting slot in the tuning stub with appropriate length rather than on the ground plane. However this paper mainly focuses on reconfigurable notch band through the introduction of slot in the ground plane. The paper is organized as follows: Section 2 brings out the geometry of the antenna. In section 3, results and analysis are presented. Section 4 concludes the work.

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2 Antenna Geometry

The structure of the proposed antenna with biasing circuit is shown in Fig. 1. The antenna consists of rectangular slot with triangular tuning stub. The proposed antenna is designed to cover the entire UWB band with reconfiguration capability. Slits are introduced to avoid the short circuit between the ground planes. Fast switching diode LL4148 is used as a switching device. In this study, FR4 substrate with thickness of 1.6 mm with relative permittivity of 4.4 is chosen to facilitate printed circuit board integration. The CPW feed is designed for 50 Ω characteristic impedance with fixed 2.4 mm feed line width and 0.5 mm ground gap. The placement of the diodes 'L_d' are desired by the effective wavelength $\lambda_e ff$ for the different notch frequencies.

$$L_d = \frac{c}{2f_n\sqrt{\epsilon_{eff}}} \tag{1}$$

where 'f_n' is the center frequency of the notch band.

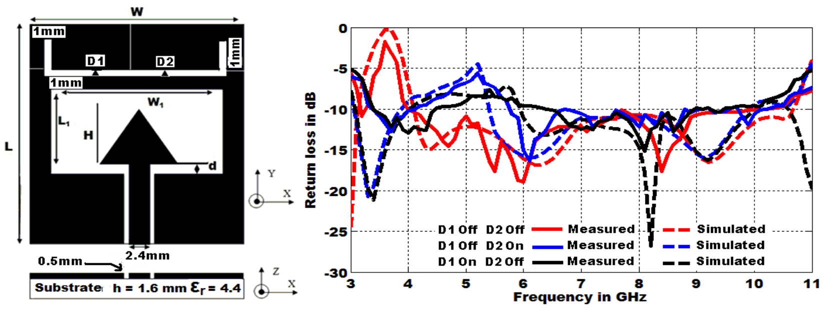

Fig. 1. Geometry of the proposed antenna and comparison of return losses.

3 Results and analysis

The analysis and performance of the proposed antenna is explored by using IE3D for the better impedance matching. The optimization was performed for the best impedance bandwidth. The detailed parametric analysis of the UWB antenna is carried out and presented in our paper [8]. The analysis and performance of the proposed antenna is explored by using IE3D for the better impedance matching. The optimization was performed for the best impedance bandwidth. Due to figure constraints the detailed parametric analysis of the proposed UWB antenna is not included in the paper. However the impact of the length variation of the ground slot due to different condition of the diodes, the current distribution, gain and group delay are studied. The comparison of the measured and simulated return losses, with different states of the diode are shown in Fig. 1, which clearly indicates that the notch frequency and notch bandwidth is varied when the slot length is varied.

3.1 Effect of ground slot length variation

The length of the ground slot is adjusted by switching the diodes placed appropriately over the slot. The switching diodes 'D_1' and 'D_2' are placed

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over the slot along the ground plane. When both diodes are in open state the effective slot length is enough to achieve the notch frequency at 3.6 GHz with frequency notch band of 3.1 GHz to 3.9 GHz, which is the WIMAX band of frequency. When D_1 is 'Off' and D_2 is 'On' the length of the slot is tuned to eliminate the band of 4 GHz to 5.3 GHz with notch center frequency of 5.1 GHz which covers the lower band of IEEE 802.11a. When D_1 is 'On' and D_2 is 'Off' the effective wavelength of the slot is adjusted such that to eliminate the upper band of IEEE 802.11a with a notch frequency of 5.6 GHz with the notch frequency band of 4.1 GHz to 5.9 GHz.

3.2 Current distribution

The simulated current distribution at different notch frequencies according to the switching condition of the diodes is presented in Figure 2, it is witnessed from the figure, the current distribution around the radiation slot is disturbed by the introduction of ground slot, which is responsible for the notch in the frequency band. If the slot length is longer the destructive interference with the main radiating slot is high which causes the notching in that band is good. When the ground slot length is decreased, the current distribution of the radiating slot is disturbed by the tuning slot is less effective compared with the longer slot size.

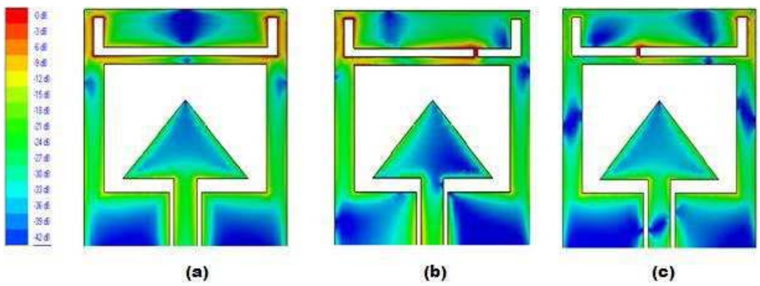

Fig. 2. Simulated current distribution for different switching conditions of diodes. a) 'D_1' and 'D_2' 'Off' b) 'D_1' 'Off' and 'D_2' 'On' c) 'D_1' 'On' and 'D_2' 'Off'.

3.3 Radiation pattern

The radiation pattern for the E plane and H plane at reconfigurable center frequencies 3.4 GHz, 5.2 GHz and 5.6 GHz are numerically computed for all the three cases of diode states are compared and noticed that the directivity gain of the radiation pattern is reduced at the notch frequencies without affecting the shape of the radiation pattern. Figure 3 (a) shows the E plane radiation pattern at one of the center notch frequency 5.6 GHz, it is bidirectional pattern and Figure 3 (b) gives the H plane pattern at 5.6 GHz, it is omni directional pattern.

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3.4 Gain

The computed gain of the proposed UWB antenna for different tuning lengths of the slot in the ground plane and without slot is compared in Figure 3 (c). It is observed that there is a gain variation at the notched frequencies when the length of the slot is tuned. which is −7.5 dBi for both diodes are 'Off' state and 0.4 dBi when D_1 is 'Off' and D_2 is 'On'. Where as it is 0.6 dBi for D_1 is 'On' and D_2 is 'Off'. The antenna without slot and the gain varies from 2 dBi to 6 dBi across the UWB spectrum.

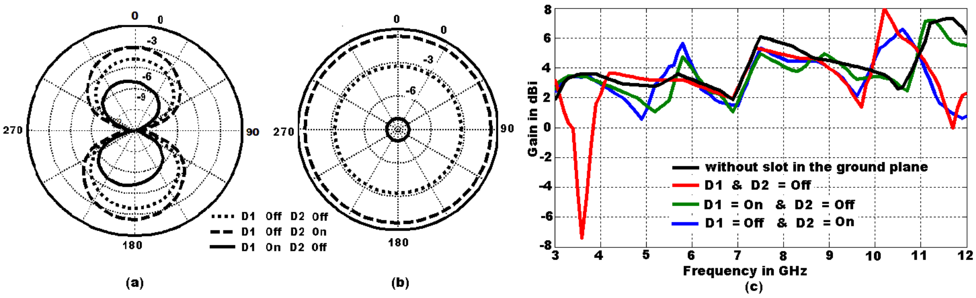

Fig. 3. a) Simulated E plane radiation pattern at 5.6 GHz. b) Simulated H plane radiation pattern at 5.6 GHz. c) Simulated gain for different biasing conditions of diodes.

3.5 Group delay

Group delay is the parameter gives how much the received signal is varied from the transmitted signal. The group delay 'τ' of the antenna is calculated from the phase of the computed 'S_{21}' by using the following equation,

$$\tau = -\frac{d\phi}{df} \tag{2}$$

where 'ϕ' is phase of 'S_{21}' in radians/sec and 'f' is frequency in GHz. It is observed from the response that the variation in the group delay for the antenna with and without slot is around 2 ns for the frequency range from 3.1 GHz to 10.6 GHz. There is a variation in the group delay at the notch band in the response which is due to notch behavior of the antenna.

4 Conclusion

This paper describes the analysis of UWB slot antenna with reconfigurable rejection bands. Measured return loss results are comparable with the simulation results. By switching the diodes, the effective length of the ground slot is tuned to the notch center frequency. The simple configuration and low profile of the proposed antenna leads to easy fabrication that may be built for any wireless UWB device applications where reconfigurable rejection bands is required. The rejection of WiMax, IEEE 802.11a and HYPERLAN/2 bands can be achieved using the proposed antenna.

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